PREDICTIVE UNCERTAINTY IN ENVIRONMENTAL IMPACT ASSESSMENT SPATIAL MODELING

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ABSTRACT

At Global level, various countries have experienced untold environmental degradation and ecological deterioration in the past century, with little or no real solution to alleviate many of these concerns. Poorly planned human interference has been the major cause. Because of the dynamic characteristics and multivariate nature of the environment, it has often been difficult to collate, analyze and interpret its data sets. However, this great complexity can be overcome with the present research of CE-EIPS modeling of EIA for an Irrigation Project using spatial technology and related technology with the ground truth verification.

This Research study deals with the modeling of Environmental impact assessment for an irrigation project i.e.Ramapada Sagar (Polavaram) Irrigation project, which has been carried out in parts of West Godavari, East Godavari and Khammam districts of Andhra Pradesh, India. About 14,400 Sq Kilometer area of remote sensing data have been collected and analyzed for environmental impact assessment by using emerging GIS technology. From the modeling analysis, the land use land cover environment, slope analysis are made. The model also conceptualizes sediment delivery from hydrologic unit into a reservoir as a multiplicative function of the potential soil detachment material (delivery ratio) and the area of the hydrologic entity. The Sediment yield index values are intended from the empirical model using for the sub watersheds and is varying from 1060 to 1500 and suggested Catchment area treatment.

It has been pragmatic during water environment analysis, an area of about 50 sq. km is under inundation at low water level +135ft (41.15m), 200 sq.km is under inundation at +140ft (42.67m), and an area of 360 sq.km is under Inundation at +150ft (45.72m) FRL.

KEYWORDS: Environmental Impact Assessment Spatial Modeling, Ramapada Sagar (Polavaram) Project, Remote Sensing (RS), Geographic Information System (GIS), Catchment Area, Land Use Land Cover, Sediment Yield Index, Water Environment, Submergence / Inundation

INTRODUCTION

Environmental Impact Assessment define and assess the potential physical, biological, socio-economic and health effects of the proposed project in a manner that allows for a logical and rational decision to be made about the proposed action (Banham, W. and D. Brew, 1996) [5].

At Global level, various countries like India, U.S, U.K, China, Germany and Japan have experienced untold environmental degradation and ecological deterioration in the past century, with little or no real solution to alleviate many of these concerns. Poorly planned human interference has been the major cause. Adequate information and appropriate technology are limiting factors for effective environmental management. Because of the dynamic characteristics and multivariate nature of the environment, it has often been difficult to collate, analyze and interpret its data sets. However, this

great complexity can be overcome with the present research of Engineering Management system Spatial Modeling of Remote sensing and Geographic Information System (GIS) and related technology with the ground truth verification. The prime objective is to study the environmental impact of the project on land use land cover environment, slope analysis, sediment yield, water environment and submergence area.

Study Area

This study deals with Environmental impact assessment for developmental project i.e.Ramapada Sagar (Polavaram) Irrigation project, which has been carried out in parts of West Godavari, East Godavari and Khammam districts of Andhra Pradesh. The Godavari River originates in the Nasik district of Maharashtra, India and flows through West Godavari district of Andhra Pradesh, India and discharges directly into the Bay of Bengal Sea.

The study area is represented in Figure 1, located between 81^0-46^1 E longitude and 17^0-13^1 N latitude, and covers parts of the Survey of India topographic sheet numbers 65G/7, 8, 11, 12.
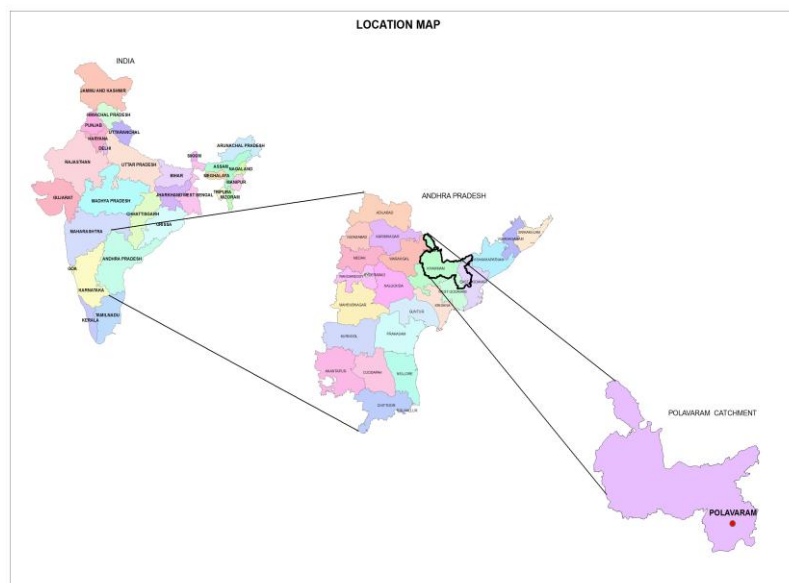

Figure 1: Location Map of Ramapada Sagar (Polavaram) Project

Study Area

The proposed project is a multipurpose project benefiting the upland areas of Visakhapatnam, East Godavari, West Godavari, Krishna and Khammam districts. It also supplies drinking water to Visakhapatnam township and villages enroute. The general climate of the command is characterized by hot summer and general dryness which gives copious rainfall. May is the hottest month with a maximum day temperature 44^0C and the minimum temperature is about 22° C. The south-west monsoon season during midst of June and ends by mid October.

The annual average rainfall is about 858.65 mm. In the study area the humidity is very high during peak rainy season. Average wind velocity varies between 4.2 kmph in April and 8.47 kmph in November. The average rainfall in the command area is 859 mm. The finalized project site consists of a zoned Earth-cum-Rockfill dam with an impervious core across the existing river course. The spillway is located in the right flank saddle and power dam on the left flank saddle. The FRL of the reservoir is proposed as +150ft (45.72m).

RESEARCH WORK SPATIAL MODEL PROPOSED

Table 1

| Model Name	Description	Major Features	Data Requirements	Out Put
CE – EIPS – RS & GIS [Civil engineering Environmental impact assessment for an irrigation project interms of submergence using Remotesensing and Geographic information system]	2D – Longitudinal, Vertical Reservoir water quantity and quality model for Environmental Impact Assessment using Remote sensing and GIS	- Description of Land use / Land cover - Assessment of Water Environment - Assessment of submergence area under various discharge flows - Allow simulation of most major physical , chemical and biological process and associated water quality constituents	**Primary Data :** - Water Quantity , Quality data and coefficients - Physical data , cross section geometry , elevations and locations of nodes; Lateral inflows and tributaries ; control structures **Secondary Data :** - River Flows, Depths, spot heights and velocities - Water Quantity and Quality targets at system control points.	- Classification of Land use / Land Cover area and suggestive crops - Submergence / Inundation area due to the Reservoir water quantity (Printed and / or plotted) - Vertical profiles and outflow values for constituents over time (Printed and / or plotted) - Reports of water quality parameter values for drinking and Irrigation purposes - Catchment area treatments - Site selection for Resettlement & Rehabilitation purposes
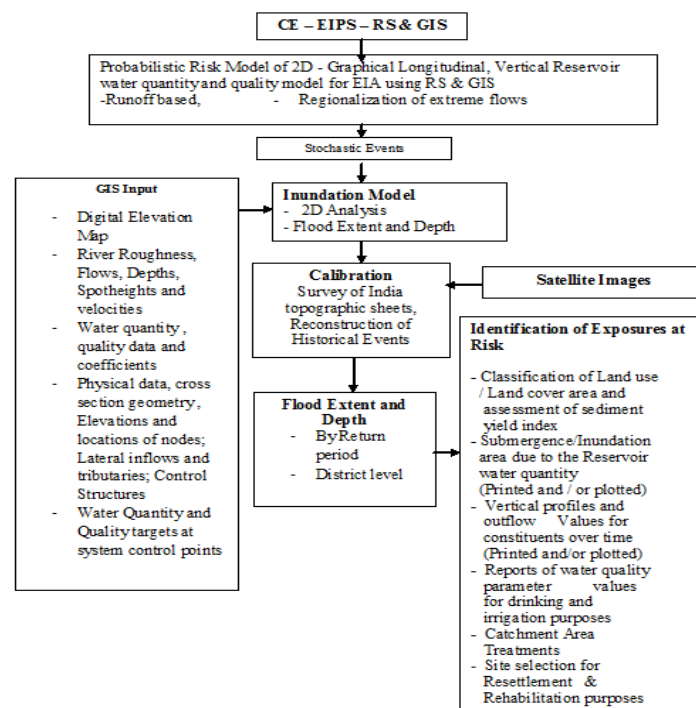
Figure 2: Flow Chart of Research Work Spatial Model Proposed on Environmental Impact Assessment for Ramapada Sagar (Polavaram) Irrigation Project

Mathematical Expressions Involved in the Model

Probability Distributions

Generalized Pareto Distribution (GPD)

Cumulative Distribution Function when P [X ≤ x] , CDF F(x) = 1 – e $^{-y}$ where

$Y = -K^{-1} \log [1 – k (x - \xi) / \alpha]$

$Y = (x – \xi) / \alpha$ for k = 0

Generalized Extreme Value Distribution [GEV]

CDF, $F_x(x) = \exp \{ - [1 – (kx – \xi) / \alpha]^{1/k} \}$ for k ≠ 0

$F_x(x) = \exp \{ - \exp[– (x – \xi) / \alpha] \}$ for k = 0

Runoff Quantity Density Function =

Derivative $f(x) = d/dx [f(x)]$

$f(x) = d/dx (1-e^{-y})$

$= -d/dx \{1-[k(x- \xi)/ \alpha]\}^{1/k}$

$= 1/ \alpha \{1 – [k(x- \xi)/ \alpha]\}^{(1-k)/k}$

X   =   Rainfall

f(x)   =   Runoff

K   =   Slope factor / Velocity

α   =   Time

ξ   =   Infiltration

Y   =   Runoff function coefficient

APPROACH AND METHODOLOGY

The study utilised the Survey of India toposheets of 1:50,000 scale for studying the catchment area, command area and also the submergence area for identification of land use land cover, slope and soils, etc. The satellite based remote sensing imageries are procured from the NRSC, hyderabad for image analysis and arriving at the land use land cover, slope, soils, surface drainage, etc. and also for preparation of catchment area treatment plan based on Sediment Yield Index method.

This study is carried out by combining the features of satellite imagery, topographic sheets and secondary maps data to produce the necessary information layers of natural resources. The data translation into thematic maps employed the GIS software Arc/Info, Arc View , Arc Map and the remote sensing software ERDAS. The Impact is determined by taking the Spot heights as reference.

RESULTS

The Following Figure 1, Figure 2 and Figure 3 are the Output of Research Work Spatial Model Proposed
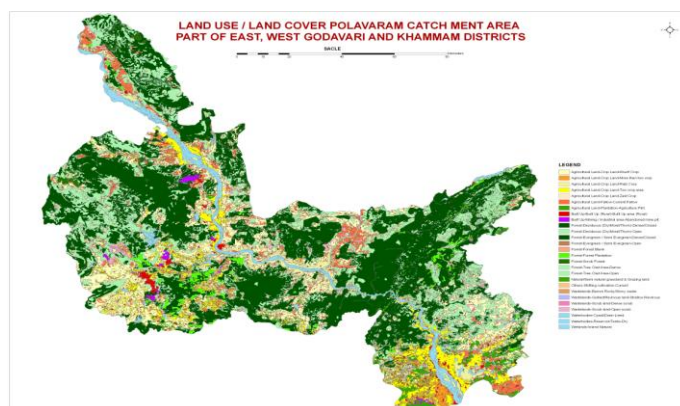
Land Use / Land Cover

**Figure 3: Shows the Land Use / Land Cover of Ramapada Sagar (Polavaram)
Catchment Area, Year 2008-09 (Satillite Data: 05.11.2008)**

The analysis of remote sensing data provided the area under different land use and land cover under different categories of the catchment and this area has been represented in Figure 3. The crop land covers 79.8% with an area of 3,92,766 ha, plantations 49,505ha, built up land occupies 23,262ha (4.72%), forest occupies a mere 0.38%, tanks and streams occupies 3,819 ha (0.82%) and scrub land occupies 19,680ha (3.37%). The major soils in the command area are moderately deep gravelly sandy loams and lateritic upland (1,92,308 ha); followed by deep fine sandy loam (1,39,403 ha). The other types of soils are deep sandy loam on undulating land, moderately deep sandy loams on rolling lands, deep clayey soils on gently sloping, very deep fine loamy / clayey soils in valley, etc. The majority of the soil types fall in land irrigability/ classification 2 & 3.
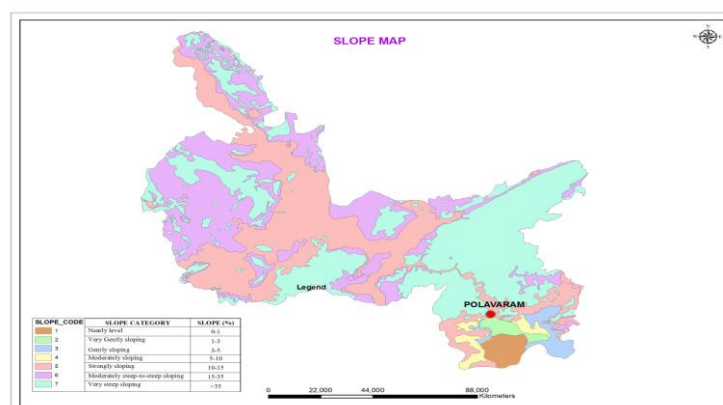
Slope

Figure 4: Slope Map

The slope map Figure 4 has been prepared for the catchment areas using 1:50,000 scale topographical maps of Survey of India showing contours of 20 m interval using tan method. The different classes of slopes have been categorized as per the guidelines suggested by All India Soil and Land Use Survey (AIS&LUS). The vertical drop is measured from the contour interval and the horizontal distance between the contours is measured by multiplying the map distance with the scale factor. Finally the slope percentage is calculated. From the figure 4, the slopes of the catchment mostly range between 1% to 5% (i.e., nearly level to gently sloping). The agriculture is practiced generally in the nearly level to gently sloping areas. In the catchment about 91.55% of the area comes under nearly level to gently sloping category (i.e., 0% - 5% slope).

Only 0.45% of the catchment area comes under moderately sloping to strongly sloping (i.e., between 5% - 15% slope). The nearly level, very gently sloping, gently sloping areas are 77.25%, 21.44%, and 0.86% respectively. From the slope map, erosion intensity can be estimated and suitable measures that are required to restrict the siltation of the proposed Reservoir by biotic treatment, engineering treatment and gully control works can be suggested.

Sediment Yield Estimation

The origin of the sediment coming into a Reservoir is mainly from its self-catchment. It has been realised that uncontrolled deforestation, forest fires, unwise agricultural practices and various faulty land uses have accelerated soil erosion resulting in a large increase of sediment flow into the streams. The model conceptualizes sediment delivery from hydrologic unit into a reservoir as a multiplicative function of the potential soil detachment material (delivery ratio) and the area of the hydrologic entity. This can be expressed as:

Sediment Yield = f (Erosivity of Soil X Delivery Ratio X Area of Hydrologic Unit)

The erosivity is simulated with the sediment yield weightage value which is based on assessment of the composite effect of assemblage of erosivity determinants whereas, delivery ratio is adjudged by the likely delivery of the eroded material into the reservoir.

Sediment Yield Index (SYI)

The Sediment Yield Index (SYI) is defined as the Yield per unit area and SYI Value for hydrologic unit is obtained by taking the weightage arithmetic mean of the products of the Weightage value and delivery ratio over the entire area of the hydrologic unit by using suitable empirical equation.

The prioritizations of smaller hydrologic units within the vast catchments are based on the Sediment Yield Indices (SYI) of the smaller units. By studying the frequency distribution of SYI values and locating the suitable breaking points we arrive at the boundary values or range of SYI values for different priority categories. The sub watersheds are subsequently rated into various categories corresponding to their respective SYI values.

$$SYI = \frac{(Ai \times Wi \times Di) \times 100}{Aw} \quad ; i = 1 \text{ to } n$$

Where   Ai   =   Area of ith unit (EIMU)

Wi   =   Weightage value of ith mapping unit

Di   =   Delivery ratio assigned to i^{th} mapping unit

n   =   No. of mapping units

Aw   =   Total area of sub watersheds

100   = Uniform area base

Method

- Preparation of a framework of sub- watersheds through Systematic delineation and codification.

- Preparation of Erosion Intensity Mapping Units (E I M U's)

- Assignment of Weightage values to various mapping units based on relative Sediment Yield.

- Assignment of maximum delivery ratios to various erosion Intensity mapping units and assessment of adjusted delivery Ratios for different sub- watersheds.

- Computing Sediment Yield Index for individual sub- watersheds.

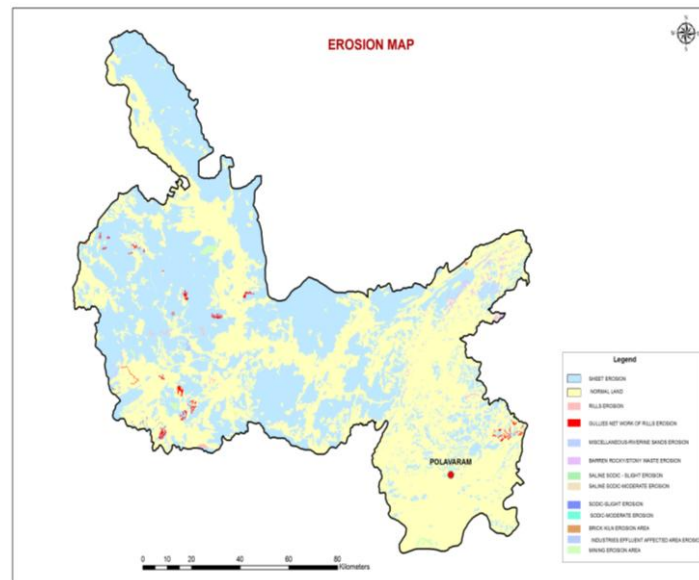- Grading of Sub watersheds into very high, high, medium, low and very low priority categories.

Figure 5: Erosion Map

Assignment of Erosivity Weightage Values

From Figure 5, the composite erosion-intensity mapping units are assigned. Relative erosivity values adjudged to be indicative of the combined effect of dynamic inter-relationship of the factors in terms of active erosivity of the units. The erosivity values are assessed by a group of workers as resultant of combined and reciprocal influence of a set of the factors namely, climate, physiography and slope, land use/land cover conditions, soil characteristics and the existing erosion.

Assignment of Delivery Ratios (DR's)

The values of delivery ratios employed as a measure of transportability of the detached soil material to the site of catchments reservoir are adjudged for individual mapping units based on the factors influencing the suspension and mobility of the suspended material. Land use/land cover condition, terrain slope configuration and soil are the main parameters considered for assessing the maximum delivery ratios to the units. The maximum delivery ratio values, assigned to mapping units, range from 0.40 to 0.95.

Categorization and Gradation of Sub Watersheds

The gradation and assignment of priority ratings to the sub watersheds are based on the descending values of Sediment Yield Index values. For deciding upon the boundaries of various priority categories, namely very high, high, medium, low and very low category, the SYI data are tabulated. The frequency distribution of the data is worked out by grouping the data in narrow bands of SYI values against the number of sub watersheds within each of the ranges.
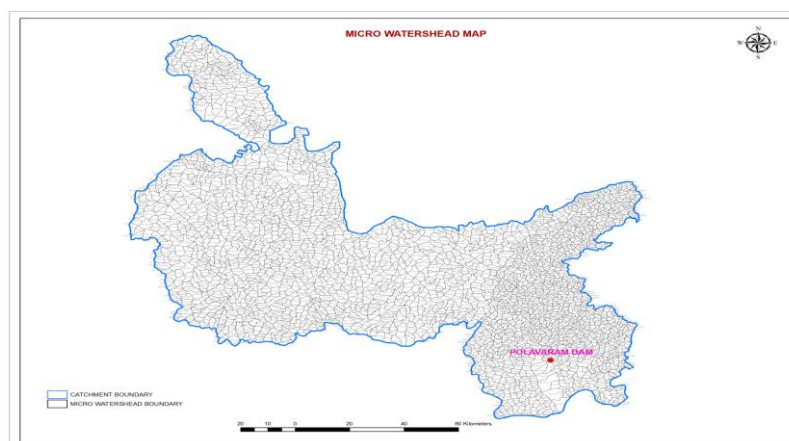
Figure 6: Shows the Micro Watershed Map of Ramapadasagar (Polavaram) Project

From Figure 3 & 4, Mapping legend for Erosion intensity, Sediment yield index of sub-watersheds are arrived and shown in Table 1 and 2.

Table 2: Mapping Legend for Erosion Intensity

Mapping Unit	Erosion Intensity	Land Use/Land Cover	Soil Depth	Weightage/ DR Ratio
1	Severe	Upland with or without scrub, Barren rocky/ stony waste area, Fallow and, Single cropped area	Very shallow	25/0.65-0.80
2	Moderate to severe	Upland with or without scrub, Single cropped area	Moderately shallow	24/0.65-0.80
3	Moderate	Upland with or without scrub, cropped area	Deep	22/0.60-0.75
4	Slight to Moderate	Single cropped and double cropped area	Moderately deep	16/0.50-0.65
5	Slight to Negligible	Double cropped area	Very deep	11/0.40-0.45

Note: Slope is Nearly level to Gently sloping (0% to 5 %)

Table 3: Prioritization of Sub Watersheds

Sl. No.	Sub-Watershed Code	Area (Ha.)	Sediment Yield Index (SYI)	Relative Priority	Priority
1	4D1C3f	6685.88	1500.0	1	Very High
2	4D1C4j	11853.32	1415.5	5	Very High
3	4D1C4h	6992.96	1304.1	10	Very High
4	4D1C4m	8128.89	1060.6	15	Low
5	4D1C5n	5576.83	1124.1	13	Medium
6	4D1C5o	800.75	1110.2	14	Medium
7	4D1C5r	3214.64	1190.0	12	Medium
8	4D1C5c	5446.67	1254.2	11	High
9	4D8A7b	1969.92	1330.6	9	Very High
10	4D8A3k	8983.24	1477.6	3	Very High
11	4E1A3a	10716.15	1389.1	6	Very High
12	4E1A3c	8284.37	1476.4	4	Very High
13	4E1A3d	9918.41	1382.2	7	Very High
14	4F1A5j	5106.11	1483.8	2	Very High
15	4F1A5k	6590.78	1356.3	8	Very High

The directly drained streams into the reservoir have been demarcated based on Survey of India toposheets on

1:50,000 scale. The base maps for the study area have been prepared showing major roads, settlements, canals and river/tank boundaries on 1:50,000 scale. The land use/land cover map was prepared. Other input data that is available for various other parameters like slope, soil, drainage, and rainfall were also considered during the preparation of treatment plan. Based on land use/land cover maps and other available information, the treatment map was prepared on 1:50,000 scale. The spatial extent of the various sub watershed wise treatment areas are given in Table 3.

The treatment plan comprising of the components such as biotic treatment with soil and moisture conservation measures, Engineering and Gully control works. The areas identified for the biotic treatment with soil conservation measures are land with or without scrub, fallow lands, barren rocky/stony area and kharif unirrigated lands. The sub watershed wise spatial distribution and extent of biotic treatment and the locations of Gully control works/ Engineering treatment are also shown in Figure 4.
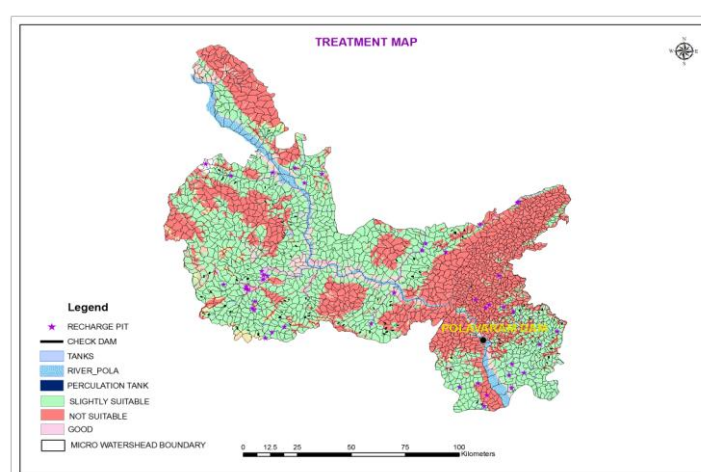

Figure 7: Treatment Map

From the Figure 7, the following biotic treatment measures are suggested in the catchment treatment plans shown in Table 4.

Table 4: Catchment Area Treatment

Sl. No.	Item	Type of Treatment	Area in sq.km.
1	**Biotic Treatment Measures**		
A	Land with or without scrub, Fallow land	Social forestry, Agro-forestry, silvipasture	168.31
B	Rainfed crop	Soil and moisture Conservation measures with Vegetation barriers and horticulture	688.95
	Total Treatment Area:		**857.26**
2	**Engineering/Gully Control Works**		
A	Gully Plugs		89 nos.
B	Rock fill dams		69 nos.
C	Check dams		40 nos.

Analysis of Water Environment

Surface Water Quality

100 Water samples were collected during the year 2007-08 at the proposed site and got analysed. It is concluded that the Godavari River water at the project site is found to be chemically suitable for irrigation and drinking water purposes.
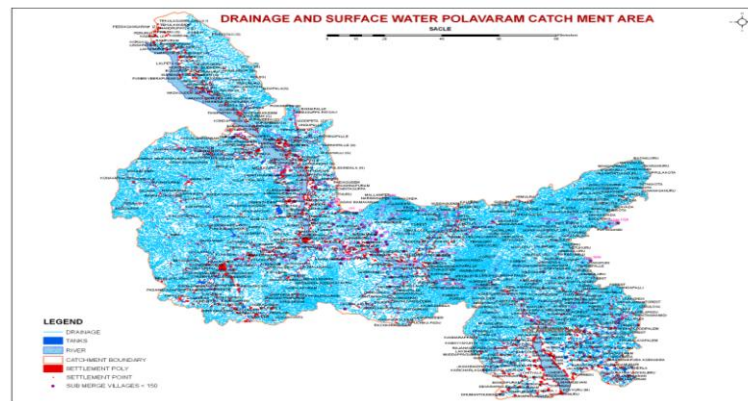
Figure 8: Drainage and Surface Water of Ramapada Sagar (Polavaram) Catchment Area

From the Figure 8, due to the construction of the Ramapada Sagar (Polavaram) on the Godavari River, an area of about **50** sq.km is under inundation at low water level +135ft (41.15m), 200 sq.km is under inundation at +140ft (42.67m),and an area of **360** sq.km is under Inundation at +150ft (45.72m) FRL.

CONCLUSIONS

The Spatial model of Civil Engineering Environmental impact assessment for irrigation project in terms of submergence using Remote sensing and GIS (CE-EIPS – RS&GIS) with ground truth verification is developed and successfully worked out and represented in Figure 2. The analysis of remote sensing data provided the area under different land use and land cover under different categories of the catchment and this area has been represented in Figure 2.

The crop land covers 79.8% with an area of 3,92,766 ha, plantations 49,505ha, built up land occupies 23,262ha (4.72%), forest occupies a mere 0.38%, tanks and streams occupies 3,819 ha (0.82%) and scrub land occupies 19,680 ha (3.37%). The major soils in the command area are moderately deep gravelly sandy loams and lateritic upland (1,92,308ha); followed by deep fine sandy loam (1,39,403 ha). The other types of soils are deep sandy loam on undulating land, moderately deep sandy loams on rolling lands, deep clayey soils on gently sloping, very deep fine loamy / clayey soils in valley, etc. The majority of the soil types fall in land irrigability/ classification 2 & 3. In general the soils are low to medium in organic carbon, low to medium in available P_2O_5 and medium to high in K_2O. Soil erosion is very limited. The tentative sequence of geological formation are : Alluvium (sand silt, clayey soil – Recent, sub-recent phrixen, Granulites – charnolite suite garnet – biotite – kondalite suite .

The slope of the catchment area is studied and represented in Figure 4. The entire drainage basin of the river comprises undulating – a series of ridges and valleys interspersed with low hill ranges, large flat areas of the type characteristic of the Indo-gangetic plains are seen except in deltas. In the catchment, very gentle and gentle slope covers 45.53%, moderate slope 5.8% and gentle to steep 48.60%. In the command area 95.85% of the area is classified under very gentle slope and 2.03% gently sloping.

The model also conceptualizes sediment delivery from hydrologic unit into a reservoir as a multiplicative function of the potential soil detachment material (delivery ratio) and the area of the hydrologic entity. The Sediment yield index values are calculated from the empirical model using for the subwatersheds and is varying from 1060 to 1500 and suggested Catchment area treatment (i.e. biotic treatment with soil and moisture conservation measures, Engineering and Gully control works) are represented in Figure 6 and are given in Table 4.

From the analysis of water environment Figure 6, due to the construction of the Ramapada Sagar (Polavaram) on the

Godavari River, an area of about 50 sq.km is under inundation at low water level +135ft (41.15m) and the mandals affected are Polavaram, Devipatnam and Burugupadam. 200 sq.km is under inundation at +140ft (42.67m) and the mandals affected are Polavaram, Devipatnam, Burugupadam , Bhadrachalam and Vara ramachandrapuram . An area of 360 sq.km is under Inundation at +150ft (45.72m) FRL and the mandals affected are Polavaram, Devipatnam, Burugupadam , Bhadrachalam, Vara ramachandrapuram, Kukunuru, Velairpadu, Kunavaram and Chintoor .

ACKNOWLEDEGMENTS

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